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(54) PROCESS AND APPARATUS FOR PRODUCING CUP SHAPED THIN-WALLED METAL WARES

(71) We, Bowco Inc., of Route 128, Blackburn Circle, Gloucester, Massachusetts, United States of America, a corporation organized and existing under the Laws of the Commonwealth of Massachusetts, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a process and apparatus for producing cup-shaped thin-walled metal wares.

The art of producing cup-shaped tubular wares from ductile metals has, heretofore, generally involved a metal forming process known as cup drawing. Said process begins with a circular "blank" of sheet metal which is placed upon a circular die means. A punch member, of appropriate diameter, is then forced axially into the centre of the metal blank and die means, thereby "drawing" the overlapping portion of the metal blank into the restricted annular space formed between the die means and punch. A variant of the above process, known as "step" drawing is often utilized in the production of thin-walled tubes. In step drawing, a circular die member has coaxially positioned therewith a plug mandrel, thereby defining an annular space between the circular die and mandrel. An oversized tube is then forced into said annular space.

While the above "drawing" processes are frequently acceptable, particularly from the standpoint of simplicity and smooth surface characteristics imparted to the products formed thereby, said processes nonetheless suffer from certain serious deficiencies. Firstly, unless the "draw" is relatively short and/or the metal to be formed exceptionally ductile, it is ordinarily necessary to repeat the aforementioned drawing steps several times utilizing progressively smaller dies, punches and plugs in order to provide overall "deep" draws, i.e. draws where the original thickness of the metal blank is to be reduced by a factor of more than about four, commonly referred to as "ironing". Accordingly, cup or step drawing to substantial depths often requires a plurality of drawing passes which, of course, is very expensive. Secondly, many metals undergo work hardening or re-crystallization during each drawing step, often rendering the product of each such drawing step unsuitable for further drawing unless specially treated, as by annealing. For instance, such items as brass small-arms cartridge cases are often formed by cup drawing in a succession of drawing steps interspersed with time consuming and expensive annealing or stress-relieving steps.

In recent years, the provision of hermetic metal/glass seals has become an increasingly important art. For instance, speciality light bulbs or piping in many chemical processes requires the provision of hermetic seals between glass and tubular metal structures. Such seals are often formed by forcing tubular molten glass over the wall of the tubular metal structure. Upon cooling and shrinking, the glass tube forms a hermetic seal with the metal tube. Further, it is known that when the wall of the tubular metal structure is both thin and tapered, a glass/metal seal of superior quality is often achieved. To reap the full rewards in the use of tapered wall tubular structures, however, it is further important that the metal surface contacting the glass be smooth and free of surface defects. All of the above discussion points to the need in the metal-forming art for a simple accurate process and apparatus for forming tapered wall tubular wares.

While swaging, and particularly rotary swaging, may at first appear to be an attractive method for producing tapered wall tubular wares, said process has been found to be useful only when the wall thickness of the resulting product is not particularly important because the swaging process tends to thicken the swaged part of the tube. Thus, a two-inch OD metal tube with a 0.100 inch wall thickness when tapered to a diameter

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of one-inch OD by rotary swaging will normally be found to have a wall thickness of approximately 0.200 at the one-inch OD section of the finished product.

Accordingly, in the past when tapered wall tubular shapes were desired, it was generally necessary to produce same by providing an excessively thick tube and thereafter tapering the walls thereof by machining, such as by taper reaming. In addition to the fact that such machining was expensive and time consuming, such machining was also found unsatisfactory because stringent tolerances for concentricity, particularly with respect to thin wall tubing, could not ordinarily be met by production machining methods. Furthermore, such machining often leaves tool marks which, as mentioned before with respect to surface defects, is a detrimental feature when the finished tubular ware is to be subsequently utilized as part of a hermetic glass/metal seal. Thus, such machined wares are often required to be even further treated by a burnishing or polishing step.

The present invention consists in a process for producing tubular cup-shaped wares which comprises:—

(A) mounting a cup-shaped metal workpiece over the tip of a mandrel comprising a continuous metal-working surface;

(B) indirectly heating said workpiece;

(C) providing a roller means spaced from the continuous metalworking surface of said mandrel whereby a nip of smaller dimension than the thickness of said workpiece is provided therebetween; and

(D) causing relative motions of the resulting mandrel/workpiece assembly with respect to said roller means, said motions comprising

(i) axial motion of said assembly through said nip, and

(ii) rotational motion between said assembly and said roller means.

The present invention also consists in apparatus for carrying out the process of the invention.

In accordance with the present invention cup-shaped tubular metal wares (hereinafter referred to for convenience as "tubular wares"), and particularly tubular wares having thin and accurately tapered walls, can be readily formed.

In accordance with the process of the present invention tubular wares having wall thicknesses of less than 0.010 inch and most preferably less than 0.005 inch are formed by positioning a cup workpiece over a mandrel and forcing the resulting mandrel/cup workpiece assembly axially into the nip provided between said mandrel and at least one roller means. The mandrel and/or roller means are rotated as the workpiece is forced into said nip.

An embodiment of the invention will now be described by way of example only, with reference to the accompanying drawings, in which:—

Figure 1 is a schematic diagrammatic longitudinal section of apparatus in accordance with the present invention for performing the process of the present invention wherein there is provided a mandrel, a workpiece positioned thereon, and a roller holding means,

Figure 2 is a schematic diagrammatic longitudinal section of one example of a product of the process of the present invention.

Referring to the drawings, the apparatus of the invention broadly comprises mandrel 3 and rollers 9 disposed substantially equiangularly and equidistantly about the axis of said mandrel 3. It is to be noted that, in the present instance, only two of three rollers 9 are shown due to the section of the drawing. However, as will be obvious to those conversant with the machining arts, the use of three rollers is indicated by the fact that rollers 9 of the depicted apparatus are spaced at 120° angles from one another. Said rollers 9 are sturdily and rotatably mounted in any appropriate static holders 11. Additionally, means are provided (not shown) to rotate mandrel 3 about its axis and to feed said mandrel 3 longitudinally and substantially coaxially through the zone defined by said rollers 9. In this context it is to be noted and understood that the longitudinal feed and rotation system provided is intended broadly to provide longitudinal and rotational motion of the mandrel relative to rollers 9. Accordingly, it is also suitable that mandrel 3 be statically mounted while holders 11 be provided with means for rotating and feeding rollers 9 axially over said statically mounted mandrel. Other permutations and combinations of such means to accomplish the intended relative motions of the mandrel and roller means are also generally suitable and will be recognized by those skilled in the art.

In a preferred embodiment of the invention, however, static holders 11 each have associated therewith a heating means, such as cartridge heaters 15. When this preferred embodiment is employed, it will normally facilitate matters substantially if holders 11 are mounted statically while provision is made to rotate and feed mandrel 3.

The particular contour of rollers 9 employed in the apparatus is not normally critical. Thus, for instance, cylindrical, spherical or divergently tapered contours are often entirely suitable. However, depending largely upon such operating parameters as the specific metal to be formed, the extent of reduction of wall thickness of the metal to be accomplished, the temperature at which operations are to take place, the number of passes to be employed to attain the finished

product, etc., it is generally preferred that rollers 9 have longitudinally stepped contours. Specifically, rollers 9 bear steps 17 and 19 constituted by roller portions having incrementally increasing diameters. The provision of such stepped roller contours can serve, practically speaking, as means for providing several forming operations with each pass of a workpiece therethrough. Accordingly, said stepped rollers 9 can often accomplish in one pass, what would normally require three or more passes when essentially cylindrical rollers are employed.

While choice of the materials of construction of the remainder of the apparatus will generally be obvious to those skilled in machine design, it is pointed out that it is much preferred that the materials of construction of rollers 9 be chosen so as to provide as hard and smooth a roller surface as possible, bearing in mind of course the particular needs of the metals and tubular wares to be formed therewith. Generally speaking, however, materials such as cemented tungsten carbide, hardened or normalised tool steel, and nitrided or case hardened steels, i.e., materials which are, or can be treated to be, harder than about Rockwell C-60 are generally much preferred as materials of construction for roller means.

Referring now to the operations of the afore-described apparatus with respect to a particular end product, cup workpiece 5 comprising a cross-rolled 0.020 inch molybdenum sheet which had been blanked, cup drawn and trimmed into a cup having an I.D. of about 0.490 inch; a height of about ¾ inch side wall 6 thickness of about 0.020 inch and base wall 7 thickness of about 0.020 inch was positioned over tapered round mandrel 3 having a tip 8 diameter of 0.485 inch and a divergent taper beginning 0.5 inches from tip 8 and extending rearwardly from said tip 8 for a distance of 1.25 inches to a diameter of 0.497 inch. Said mandrel was heated to and maintained at a temperature of 400°F by means of thermostatically controlled cartridge heater 16 embedded therein, thereby to directly heat said mandrel and to indirectly heat the workpiece by conduction of heat thereinto through said mandrel. Next, said mandrel 3, bearing the cup workpiece 5 thereon was rotated at a speed of 500 r.p.m. and fed at a rate of 0.001 inch/revolution coaxially into the area defined by step-contoured cemented tungsten carbide rollers 9 having three portions having diameters in increasing order of 1.00 inch, 1.02 inches and 1.04 inches, respectively. Prior to start-up, said rollers were adjusted so as to provide a 0.0015 inch clearance between their respective 1.04 inch diameter steps and the 0.497 inch diameter portion of tapered mandrel 3. Additionally, holders 11 were each continuously heated by means of cartridge heaters 15 so as to minimize heat flux into the rollers and sundry apparatus from the workpiece undergoing forming. When the mandrel tip 8 had traversed through the space defined by rollers 9 to a depth of about 1.2 inches, mandrel 3 was withdrawn and the formed tubular ware removed from the mandrel. Said ware was then trimmed to an overall length of 31/32 inch and inspected visually and dimensionally. The surface of the finish cup product was found to be smooth and substantially free of burrs, tool marks or other surface defects and was further adjudged to have a finish of about 20 μ.in. rms. Dimensionally, the ware was found to possess a uniform O.D. of about 0.530 inch and a substantially linear internal taper having a thickness of 0.02 inch at the base of the vertical wall and tapering to a thickness of 0.0015 inch at the open mouth thereof.

Generally speaking, any metal, metal alloy or mixture thereof having suitable ductility constitutes a suitable metallic material for forming by the process of the invention. While direct measurement of ductility may be had by resorting to analytical tests such as the Vickers, Erichson or Olson tests, a physical parameter generally more readily extracted from the literature than data relating to any of the above-mentioned tests is percent elongation at yield. Said parameter also constitutes a good indication of ductility. Suffice it to say, therefore, that any metal material having an ultimate percent elongation at yield of at least about 10 percent is suitable for forming by the practice of the invention. Preferably, however, said material will possess an ultimate percent elongation of at least about 20 percent.

As will be readily recognized by those skilled in the art, the physical and thermal history of a metal often determines its elongation properties and such properties may often be further altered or modified by suitable treatment of the metal, such as by annealing. Accordingly, the above elongation criteria are intended to be imposed upon the metal material subsequent to the forming thereof into cup workpiece 5. Further, when said workpiece 5 is to be formed at elevated temperatures, the present elongation criteria are to be taken at the intended temperature of operations. Specific examples of normally suitable metal materials for forming by the process and apparatus of the invention are: wrought iron, hot or cold rolled iron, structural steels, SAE 1300 steel, SAE 4340 steel, SAE 1112 cold rolled steel, 18-18 stainless steel, aluminum, 17 ST aluminum, annealed copper, brass, phosphor-bronze, Monel metal, molybdenum, zirconium, titanium, nickel, German silver, gold, platinum, rhodium, zinc, beryllium, cobalt, iridium, magnesium, palladium, tantalum, vanadium,

The present invention is particularly useful, however, with molybdenum, copper, nickel alloys and particularly nickel-iron alloys and tantalum which appear to lend themselves particularly well to the present process and which are very difficult to handle by conventional processes.

In the practice of the invention, it has been noted that when rolled sheet metals are utilized as starting materials, it is often desirable that said sheet metals be of the cross-rolled variety rather than those rolled in one direction. This is particularly important when certain metals are employed which are known to have significantly higher tensile strengths parallel to the direction of roll than at 90° thereto. For example, molybdenum, when utilized in the present invention in the form of a unidirectionally rolled sheet frequently fractures or produces uneven surfaces. When molybdenum has been cross-rolled, however, this problem either does not occur, or occurs only to a lesser degree.

Cup workpiece 5 is generally described as a cup shaped ware having a side wall 6 of sufficient thickness to provide a volume of material sufficient to substantially completely fill the nip between mandrel 3 and roller means 9 for the entire length of the ultimately formed tubular product. Preferably, a slight excess of metal material will normally be provided.

Major practical purposes served by cup workpiece 5 are of course to provide (1) a sufficient volume of metal material for forming; and (2) a convenient shape which, when emplaced on mandrel 3, is stable thereon until the actual forming operation of the invention is under way. Accordingly, it is only necessary that said cup workpiece have a wall 6 length sufficient to ensure said stability, however, it may also obviously be as long as desired. In this context, it is important to note that the process of the present invention does not normally result in significant reduction in the thickness of base wall 7 of cup workpiece 5. Accordingly, when determining the volume of material necessary to achieve the above-described complete fill between mandrel 3 and roller means 9, the volume of material to be employed in base wall 7 should normally be discounted. Base wall 7, however, serves the purpose of providing a thrust member against which mandrel 3 is forced during operations. Accordingly, the thickness of said base wall 7 should be chosen, bearing the strength of the metal material in mind, so as to be sufficient to withstand the operational thrust loads imposed thereupon by said mandrel 3 without fracture, tearing or substantial distortion thereof. Further, the I.D. of the workpiece cup is beneficially chosen so as to provide a press-/ or slip-fit thereof over the mandrel.

The particular method utilized in forming workpiece 5 is normally non-critical provided that the finished product adheres to the above-described dimensional and physical criteria. Accordingly, said cup may be formed by standard cup drawing,/swaging, powder metallurgical techniques and the like.

The feed rates and rotational speeds employed during the forming operation of the invention are also subject to wide variation. The choice of said feed rate and rotational speed will be dictated, to a large extent, by such parameters as the temperature of operations, the material to be formed, the thickness of the cup workpiece and particularly the relation of said thickness to the thickness of the intended end product tubular ware, the form of the rollers, etc. Generally, it can be said that the more ductile the metal of the cup workpiece, and/or the less the reduction in thickness of the sidewall thereof contemplated, the faster can be the feed rate. Nevertheless, it is important that the feed of the mandrel into the rollers be accomplished smoothly and substantially continuously as opposed to a step-wise, discontinuous fashion. Such can be provided by the use of a jack screw feed mechanism or the like. The final choice of feed rate and rotational speeds to be employed in any given case can be determined in practice.

With respect to temperature of operation, it will be recognized that many metal materials have definite optimum forming temperature ranges. For instance, we have found that cross-rolled molybdenum can generally be best formed in the process of the invention at temperatures of between about 300°F and about 500°F and most preferably between 375°F and about 425°F. However, the optimum temperature ranges to be employed for other metal materials will obviously vary. Accordingly, suffice it to say that elevated operational temperatures will often be preferred in the practice of the invention.

The particular method by which the workpiece and forming apparatus are heated is not normally critical. For example, hot gases may be flowed through the operational environment, or flames may be impinged on the rollers, workpiece and mandrel. The employment of electric cartridge heaters as previously described, however, represents a greatly preferred expedient for performing the heating function due, in large measure, to the simplicity of the apparatus required and the excellent temperature control normally achievable therewith.

While a single roller means 9 may be employed in the practice of the invention, it will be realised that the biasing forces brought to bear against the mandrel by a single roller during operations will normally

be rather great. Accordingly, it is suggested that when the use of a single roller means 9 is contemplated, its use be restricted to those operations in which mandrel 3 has a thickness reduction to be accomplished on sidewall 6 of cup workpiece 5 is small or conversely, that means be provided to support mandrel 3 against the biasing forces encountered during operations. Much preferred, however, is an arrangement of a plurality of roller means 9 in which the vector sum of the aforesaid biasing forces encountered during operations is substantially zero. In the case of a two-roller arrangement, therefore, this suggests that the rollers be positioned 180° from one another. In the most preferred three-roller arrangement, previously described, the positioning of the rollers will be 120° from one another. In this manner, therefore, the major operational forces encountered by the mandrel during operations will be compressive forces due to the pressure exerted thereon through the workpiece by the rollers and torsional forces encountered as a result of the rotation of the rollers relative to the mandrel. The cylindrical shape of the mandrel, however, ideally befits this element to readily withstand such compressive and torsional forces.

Obviously, many changes and additions can be made in the above descriptions of the apparatus and process of the invention, without departing from the scope of the invention as defined by each of the appended claims. For instance, while not specifically mentioned above, various lubricants can be employed during operations.

Also, the forming of a tubular ware in accordance with the invention can be undertaken incrementally, i.e. in a series of passes of the mandrel into the space defined by the roller means. Further, said roller means may be adjusted to narrow the nip between the mandrel and themselves prior to each such pass therethrough. If necessary or desirable, the workpiece may be annealed or stress-relieved between such passes.

Additionally, while the above description has been generally limited to the production of tapered wall tubular wares, it is obvious that the process and apparatus are also entirely suitable for the production of straight wall tubular wares by the simple expedient of employing a straight rather than tapered mandrel as explicitly shown and described.

Accordingly, it will be apparent that many different embodiments of this invention may be constructed; therefore, the above description and drawings are not intended to be limiting of the invention except as is expressly indicated in the appended claims,

WHAT WE CLAIM IS:—

1. A process for producing tubular cup-shaped wares which comprises:

(A) mounting a cup-shaped metal workpiece over the tip of a mandrel comprising a continuous metal-working surface;

(B) indirectly heating said workpiece;

(C) providing a roller means spaced from the continuous metalworking surface of said mandrel whereby a nip of smaller dimension than the thickness of said workpiece is provided therebetween; and

(D) causing relative motions of the resulting mandrel/workpiece assembly with respect to said roller means, said motions comprising

(i) axial motion of said assembly through said nip, and

(ii) rotational motion between said assembly and said roller means.

2. The process of claim 1 wherein said indirect heating of said workpiece is achieved by direct heating of said mandrel and the heat therefrom is conducted into said workpiece.

3. The process of claim 2 wherein said direct heating of said mandrel is achieved by an electric cartridge heater embedded therein.

4. The process of the preceding claim wherein at least two said roller means are positioned substantially equiangularly about the metalworking surface of the mandrel.

5. The process of any preceding claim wherein in addition to said indirect heating of said workpiece, the or each of said roller means is heated predominantly by means of a source other than said heated workpiece.

6. The process of any preceding claim wherein said cup-shaped metal workpiece is mounted over the tip of said mandrel in slip-fit or press-fit relationship therewith.

7. The process of any preceding claim wherein the or each of said roller means is maintained in a fixed position while the mandrel/workpiece assembly is rotated and concurrently axially moved through said nip.

8. The process of any preceding claim wherein said workpiece comprises molybdenum, copper, nickel or tantalum.

9. The process of any preceding claim where the or each of said roller means has at least one longitudinally stepped contour of increasing diameter.

10. The process of any preceding claim wherein the metalworking surface of said mandrel is divergently tapered and the or each of said roller means is maintained at a fixed distance from the longitudinal axis of said mandrel throughout a step (D), thereby to produce cup-shaped wares having internally tapered walls.

11. The process of claim 10 wherein the ware produced has a wall thickness at the thinnest point thereof of less than 0.01 inch.

12. The process of any preceding claim wherein said workpiece comprises cross-rolled molybdenum and wherein said work-

piece is indirectly heated to a temperature of between 375°F and 425°F.

13. A ware produced by the process claimed in any of claims 1 to 12.

14. A ware produced by the process of any one of claims 1 to 12 and substantially as described herein with reference to and as illustrated by the accompanying drawings.

15. A process substantially as described herein with reference to Figure 1 of the accompanying drawings.

16. Apparatus for forming tubular cup-shaped metallic wares comprising: a mandrel, at least a portion of the circumferential surface of which comprises a continuous metalworking surface; means to heat the mandrel, thereby to indirectly heat a workpiece carried thereon; at least one metalworking roller means spaced from the metalworking surface of said mandrel, thereby to define a metalworking nip therebetween; and means to provide relative axial and rotational motion of said mandrel with respect to said roller means.

17. The apparatus of claim 16 wherein an electric heater means is embedded in said mandrel.

18. The apparatus of claim 16 or claim 17 wherein each said roller means is provided with means for heating thereof.

19. The apparatus of any one of claims 16 to 18 and comprising a plurality of roller means spaced substantially equiangularly about the metalworking surface of said mandrel.

20. The apparatus of any one of claims 16 to 19 wherein the metalworking surface of said mandrel is tapered and each said roller means is spaced at a fixed distance from the longitudinal axis of said mandrel.

21. Apparatus substantially as described herewith with reference to and as illustrated by Figure 1 of the accompanying drawings.

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1394105 COMPLETE SPECIFICATION

1 SHEET *This drawing is a reproduction of the Original on a reduced scale*

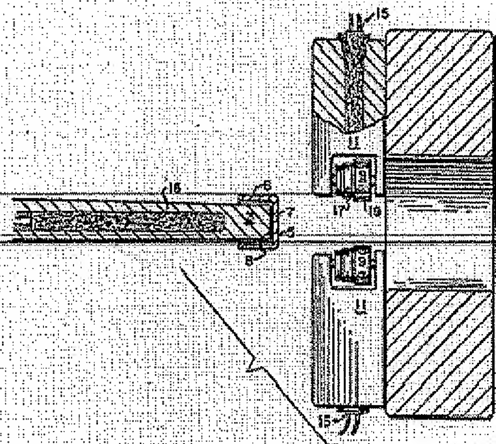

FIG. 1

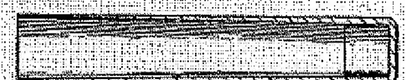

FIG. 2